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FISKERIDIREKTORATETS SKRIFTER
Serie Havundersøkelser
(*Report on Norwegian Fishery and Marine Investigations*)
Vol, VII. No. 5
Published by the Director of Fisheries

On Periodical Variations in the Yield of the Great Sea Fisheries and the Possibility of establishing Yield Prognoses

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PER OTTESTAD

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A.s John Griegs Boktrykkeri, Bergen

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The statistical returns of the yield of the great sea fisheries show that there are great fluctuations in the catches from year to year and from period to period. Thus the broken curve at the bottom of Fig. 1 (page 10) shows the fluctuations of the number of skrei caught in the Lofoten area of northern Norway in the different years from 1885 to 1939. These fluctuations make the planning of the fishing industry difficult. It is obvious that if it were possible in some way to forecast the size of the annual catches for a short future period — 5 or 10 years — the planning of the economical exploitation of the stock of fish would be greatly simplified. Even if it were possible only to tell with some certainty that a future 5-years period ranges among the good, the average or the poor 5-years periods, much would be gained.

These fluctuations in the yield have been made subject to intensive research ever since the scientific fishery investigations were started. The ultimate aim of these researches has been to find the causes of these fluctuations. And even if our knowledge as to these causes is far from complete, much information has been gathered. HJORT (1914) succeeded in proving that the size of the year-classes of the same stock fluctuates greatly and concluded from this that the main cause of the fluctuations in the annual yield had to be sought in the fluctuating renewal of the stock of fish. As to the causes of the fluctuations in the size of the year-classes more hypotheses have been forwarded, but there has not yet been given any generally accepted explanation.

Researches in the later years have proved that considerable correspondence can be found between these fluctuations in the size of the year-classes and the fluctuations in the annual yield. In some cases it has been demonstrated that this correspondence is so close that it appears to be possible to forecast the size of the catch in the next year. In the Report on the skrei fisheries in Lofoten 1939 ROLLEFSEN has published the result of his computation of the yield in 1940 (ROLLEFSEN 1940). Assuming the fishery otherwise normal in 1940, the forecast of the yield amounts to 30 million skrei. It may be possible — as I hope to demonstrate in this article — to forecast the yield in quite a different way,

and this other method when used on the same problem gives a forecast of the yield in 1940 which amounts to the very same number of skrei. In the season in question the actual yield was 25 million skrei, but for various reasons the fishing season was shorter than usual.

The yield depends, of course, on other factors than the size of the stock. The weather conditions certainly make differences from year to year and in some cases the price of fish products and other market conditions may influence the yield. It is also well known that hydrographical conditions have some influence on the migration of the fish to the fishing grounds. It is obvious, however, that if the fluctuations in the size of the stock were eliminated, the fluctuations in the yield would be diminished.

If it were possible in some way to describe the fluctuations in the relative size of the stock by means of a curve, the fluctuations in the yield measured from this curve would be much restricted compared with the total fluctuations. But as there are always other factors that make themselves felt, there will still remain fluctuations in the yield. In consequence the forecast of the yield by means of the fluctuations in the size of the stock would appear to be more or less reliable as the other factors influence the yield in a less or more dominant way.

Observations of the age composition of samples of young fish point to the conclusion that the size of the year-classes is determined at an early stage in the life history of the fish. These observations on carefully planned samples may, therefore, be used as a material for computation of the relative size of the different year-classes at the time when these enter the stock of fish which is exploited through fishing. Using these same observations, a judgement may also be made as to the future biological foundation of the fishing industry. This method of attack has, however, been proved to be both expensive and far from simple in practice. There are also some other methods in use, such as that employed by Rollefsen (1940).

There is still a method of attack not yet taken into account, to which I want to draw the attention of biologists. The foundation of this method is a careful study of those factors which are the main causes of the fluctuations in the size of the year-classes and thus also the main causes of the fluctuations in the quantitative renewal of the stock. Now, our knowledge of these factors is far from complete. We do not know for instance which factors are the main causes. If it can be proved, however, that these factors are of such a nature that their influence on the renewal of the stock is periodical and the periods can be approximately specified, much would be achieved even if these factors themselves remain unknown.

In recent years students of forestry and botany have investigated with great energy the variation of the width of the annual growth-zones in forest trees. These investigations point to the conclusion that the series of growth zones are composed of a relatively small number of periodical or period-like variations. As the various reports on these investigations cannot be reviewed in a short article as the present, I am bound to refer the reader to the extensive literature concerning the subject and to restrict myself to say that in my opinion there is no doubt that the influence of the different factors determining the width of the annual growth-zones are periodical. The periods are, however, perhaps not quite permanent, in any case when very long series such as 200—300 years are considered.

ORDING (1941) has investigated the variation of the annual growth-zones of Norwegian pine and spruce. His longest series of observations (pine) has been collected in Sørfold, a district situated close to the Lofoten area. Using the information obtained by ERLANDSSON (1936), ORDING has demonstrated that certain periodical variations assert themselves in the series. The most prominent periods have the following lengths:

2¾ years, 8½ years, 11 years, 17½ years, 23 years, 35 years and 57 years.

The lengths of the periods cannot, of course, be specified quite exactly and are, therefore, only approximate. The periods which will be referred to later, are those of 11 years, 17½, 23 and 57 years. The phases of the different periods can be given by means of the position of the maxima. Within the period discussed here, these positions or years are:

the	11-years	period:	1875, 1886, 1897, 1908, 1919 and 1930.
»	17½	—»—	1865, 1882½, 1900, 1917½ and 1935.
»	23	—»—	1869, 1892, 1915 and 1938.
»	57	—»—	1873 and 1930.

These periodical variations may be considered as indicating varying influences of those climatic factors which determine the growth rate of the pine within a certain geographical region. It must be legitimate to assume that these same climatic factors also make themselves felt in some other biological phenomena within the same region. As Sørfold, where ORDING has collected his material, is situated close to the Lofoten area and as the development of the skrei fry takes place in the surface layers of the sea in this region, these same climatic elements are possibly also affecting the death rate of the skrei fry. Now, if this reasoning is correct, there must exist a more or less close agreement between the

variation of the size of the year-classes of the skrei and the variation of the width of the growth zones of the pine.

It is, obviously, premature to go further on this track of thinking. We have unfortunately too scarce information regarding those factors which determine the death rate of the skrei fry and those climatic factors which may be of account in this connection. Our ignorance should not, however, prevent us from formulating the hypothesis that a correspondence exists between the variations of the size of the year-classes and the variation of the width of the growth zones and from trying to compute the hypothetical fluctuation of the annual yield of fishery. The result originating from this computation would prove or disprove more or less convincingly whether or not the hypothesis is in accordance with reality.

It is no easy task to handle this problem. The series of observations of the annual catches is too short to be treated with the ordinary method of period analysis. Thus the material used here is the number of skrei caught annually in the Lofoten area in the relatively short period from 1885 to 1939. Lacking the opportunity to use the ordinary method, I have tried to combine the four mentioned periods revealed by the analysis of the series of growth zones of pine, in such a way as to get the best approximation to the observations of the yield. The lengths and phases of these periods are given above. In the computation tables these periods are substituted by sine functions.

The periodical variations revealed by the analysis of the growth zone series, are certainly not wholly permanent. In any case there are alterations of the amplitudes. I may refer the reader to ORDING (1941), Table 24, page 231. As my series of observations is relatively short (only 55 years), I have disregarded this variation and used the periods as permanent components.

The effects of the factors influencing our phenomenon are possibly not independent. If, for instance, three or four periods reach their maximum at about the same time, inter-phenomenal factors may make themselves felt, preventing the maximum effects to cumulate in full force. In a plant for instance, there are certainly internal factors which may prevent the external factors from asserting themselves in the annual growth as a simple cumulative process in those cases when these external factors are at the same moment in their most favourable or most unfavourable stage. As a consequence of this we should not, perhaps, use sine functions as algebraic expressions of the effect of the external factors. Now, in course of my researches there also arose a number of other problems and I had only to cut all of them out in order to come to a preliminary conclusion.

From his studies of the age composition of large samples of skrei in the Lofoten area ROLLEFSEN (1933) came to the conclusion that a year-class contributes to the stock for the first time at an age of 6 years. The annual contingent increases until an age of 10 to 11 years and from that age it decreases. The alteration of these annual contingents can not yet be exactly specified, and there are reasons for assuming that the development is not exactly the same in all year-classes. There is thus reason to believe that there is some difference between a fast growing and a slowly growing year-class. Lacking exact information on this point we must use average data. The numbers used here in order to calculate the annual contingents of the different year-classes to the stock of skrei, are obtained through graduation of observations of the age compositions of a large number of samples (not yet published) which ROLLEFSEN most kindly has placed at my disposal. The numbers are the ratios of the contingent $h(t+1)$ of a year-class at the age of $t+1$ years and the contingent $h(t)$ of the previous year. These ratios are:

$$h(7)/h(6) = 11,\ h(8)/h(7) = 5{,}7,\ h(9)/h(8) = 2{,}3.$$
$$h(10)/h(9) = 1{,}2,\ h(11)/h(10) = 0{,}7,\ h(12)/h(11) = 0{,}6.$$
$$h(13)/h(12) = h(14)/h(13) = \ldots\ldots\ldots\ldots = 0{,}5.$$

The technical method of computation which is used, can be described shortly as follows. First the values of the four sine functions which are taken as representatives of the periods, are calculated for each calendar-year. The lengths and phases are given above. These values are then used as relative expressions of the effect of the four factors (or factor-complexes) influencing the size of the different year-classes. Now, these effects make themselves felt in the stock of skrei 6, 7, 8 ..... years later. In order to get the correct figures we must, therefore, calculate the product of each sine value and in turn the different ratios describing the alteration in the annual contingent of the single year-classes. The annual sum of the numbers obtained in this way, will then stand for the relative effect of each factor on the size of the stock. For illustration Table 1 is published. It is a short cut in the computation table of the effect of the 11 years period factor.

The figures obtained in this way are graphically given at the top of Fig. 1 (the four uppermost curves). The annual sum of these figures is graphically given in curve no. 5 in the same figure. At the bottom of this figure the broken curve is a graph of the annual number of skrei caught in the Lofoten area. It will be seen that there is a close resemblance between these two curves. Both curves have maximum points in the years 1895 and 1929. The hypothetical curve has in addition a

Table 1.

Years	Year-											
	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903
	Sine-											
	÷ 96	÷ 66	÷ 15	+ 42	+ 84	+ 100	+ 84	+ 42	÷ 15	÷ 66	÷ 96	÷ 96
	÷	÷	÷	+	+	+	+	+	÷	÷	÷	÷
1913	14	19	9	48	193	455	765	765	545	4 800	11 610	16 610
1914		9	4	24	96	228	382	382	273	2 400	6 980	11 610
1915			2	12	48	114	192	191	136	1 200	3 490	6 980
1916				6	24	57	96	97	68	600	1 745	3 490
1917					12	28	48	48	34	300	872	1 745
1918						14	24	24	17	150	436	872
1919							12	12	9	75	218	436
1920								6	4	38	109	218

maximum point in 1907 and this point coincides with the maximum catches in 1906 and 1907. Further the hypothetical curve has a minimum point in 1935—36 and this corresponds to the minimum catches in the same years.

The figures behind the four uppermost curves in the figure are only relative expressions of the effects of the four factors. In order to get figures which are comparable with the numbers of skrei caught, we have to compute a weighted sum. Using x_{11} as the symbol of the effect of the 11-years periodical factors, x_{17}, x_{23} and x_{57} as symbols of the effects of the other factors and y as a symbol of the hypothetical number of skrei caught, we have:

$$y = a + b.x_{11} + c.x_{17} + d.x_{23} + e.x_{57}$$

In order to find the values of a, b, c, d and e I have used the Method of Least Squares. The values found in this way are:

$$a = 20{,}81,\ b = 0{,}09,\ c = 0{,}11,\ d = 0{,}05,\ \text{and}\ e = 0{,}14$$

I want to warn against the thought that these values are absolute expressions of the significance of the various factors considered as causes of the fluctuations in the size of the year-classes. They are only those values that should be used in order to get the best approximation to the observations by means of the four selected periodical variations.

The hypothetical numbers of skrei are graphically given at the bottom of Fig 1. It will be seen that there is a close agreement between the observed and the computed numbers. The index of correlation is equal to 0,84. There are great discrepancies, of course, but taken as a whole, the main character of the two curves is the same. More diffe-

See text.

class											
1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	Sum (rounded figures)
value											
÷ 66	÷ 15	+ 42	+84	+ 100	+ 84	+ 42	÷ 15	÷ 66	÷ 96	÷ 96	
÷	÷	+	+	+	+	+	÷	÷	÷	÷	
9 510	940	462	84								÷ 413
11 430	2 160	2 635	925	100							÷ 301
8 010	2 600	6 050	5 270	1 100	84						÷ 94
4 800	1 830	7 275	12 100	6 270	925	42					+ 144
2 400	1 090	5 085	14 550	14 410	5 270	462	15				+ 335
1 200	545	3 060	10 170	17 320	12 100	2 635	165	66			+ 419
600	273	1 530	6 120	12 120	14 550	6 050	940	725	96		+ 370
300	136	765	3 060	7 280	10 170	7 275	2 160	4 130	1 060	96	+ 203

rences can also be accounted for by facts known to us — such as weather conditions, market conditions a. s. o. — but I do not find it necessary to enter into details.

In my opinion the agreement between the two curves points to the conclusion that the fluctuations in the annual yield of the skrei fisheries of Lofoten are caused by factors the effects of which are periodical. In any case it certainly will pay to carry on these researches on a much bigger scale. First, however, new analyses of the periods of the annual width of the growth zones in trees should be carried out in order to produce better data as to which periodical variations should be tried. Better figures of the annual contingents of the single year-classes to the stock of skrei would also be desireable.

If it were possible to give a reliable proof that the fluctuations in the annual yield are as to the main characters a composition of a relatively small number of periodical components, and it were possible to specify, approximately, the dominant periodical components, a method were found by means of which a forecast of the annual yield can be made. Such a forecast can only be made under the assumption that the fishing technique remains unaltered, in any case if the forecast shall include specification of the absolute size of the yield. Even if however, the technique is altered, such a forecast would help towards simplifying the planning of the fishing industry.

If the hypothetical curve in Fig. 1 were carried on to the right, a forecast of the annual yield of the Lofoten skrei fisheries would be given. As mentioned above, the forecast of the yield in 1940 amounts to 30 million skrei. It serves no end to carry on these calculations until more reliable and more far-reaching investigations are accomplished.

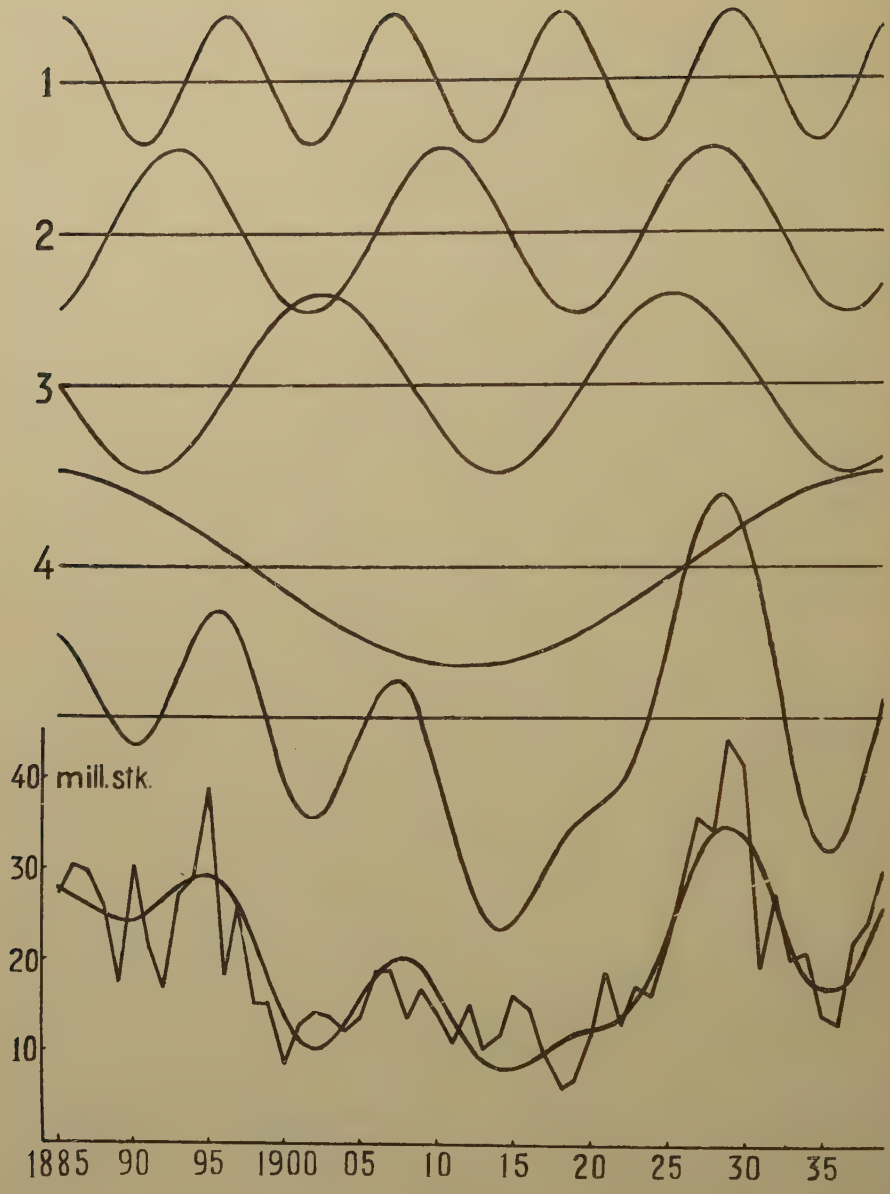

Fig. 1.

During the later years there has been an increase in the annual yield. This increase seems to be a sign of a new profitable fishing period.

I am, of course, aware that the result of this preliminary investigation can not be taken as a reliable proof of the hypothesis in question. It is also a fact that the method which I have employed, is open to

criticism and must be improved. Still it seems to me that the result is so promising that it will certainly pay to carry on the investigation. But as this would mean many years of future work and I am personally lacking the opportunities for such investigations, I have found it worth while to publish this short account of my ideas and the results of the preliminary research.

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